



# A global database of spectral surface emissivity for the entire longwave spectrum: development, validation, and application

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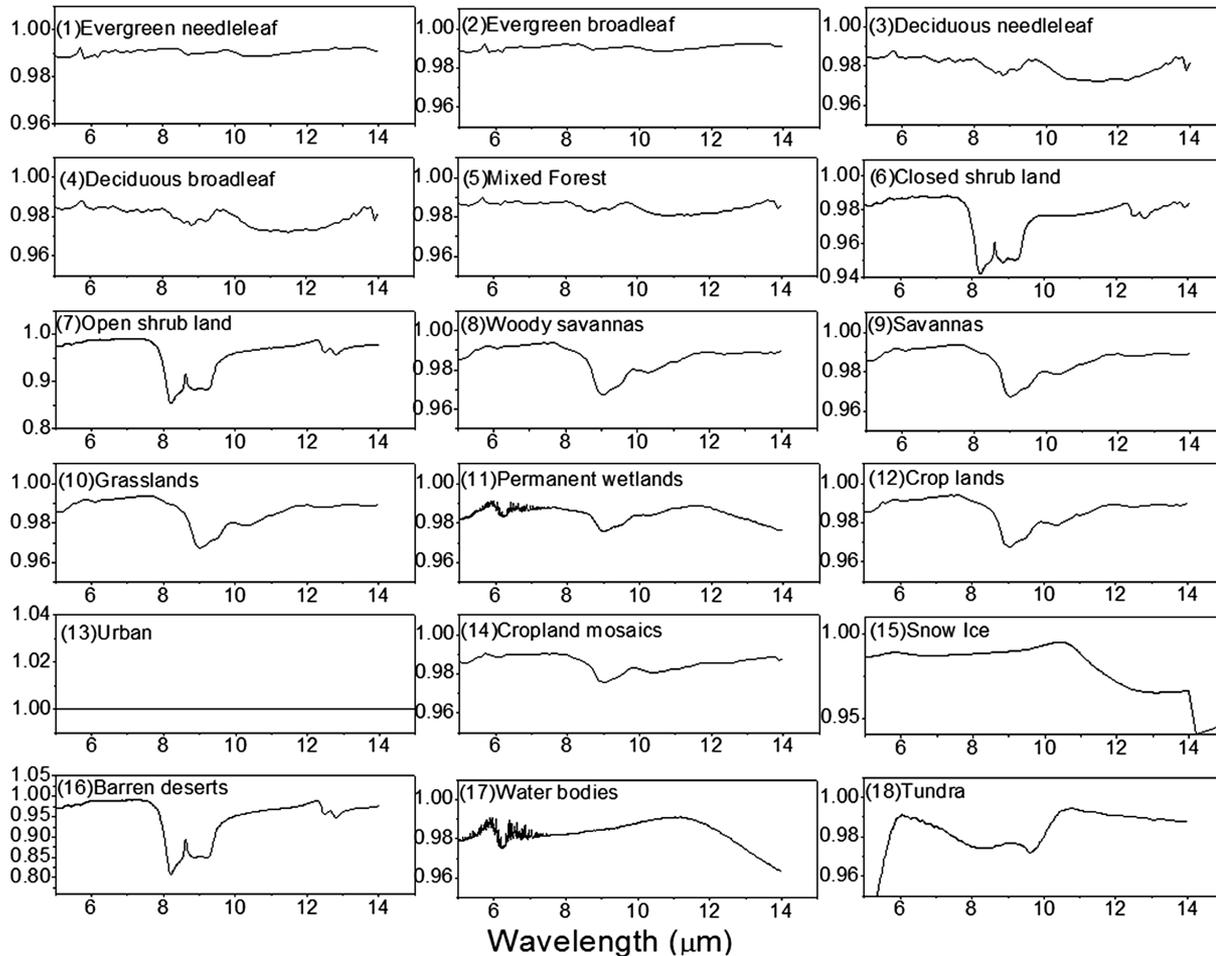
# Outlines

- Motivations
- Constructing the global data sets
  - First-principle calculation
  - Anchoring with MODIS retrievals
- Validation against IASI retrievals
- Impact on the OLR calculation



# Motivations

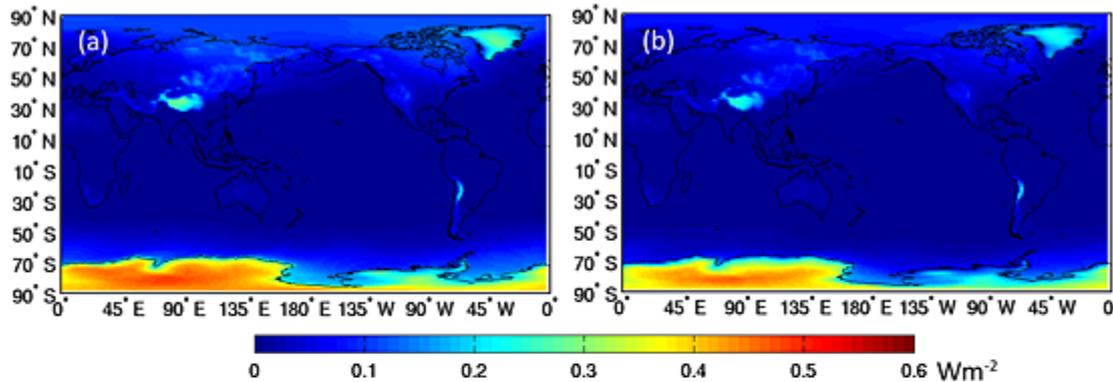
Surface spectral emissivity



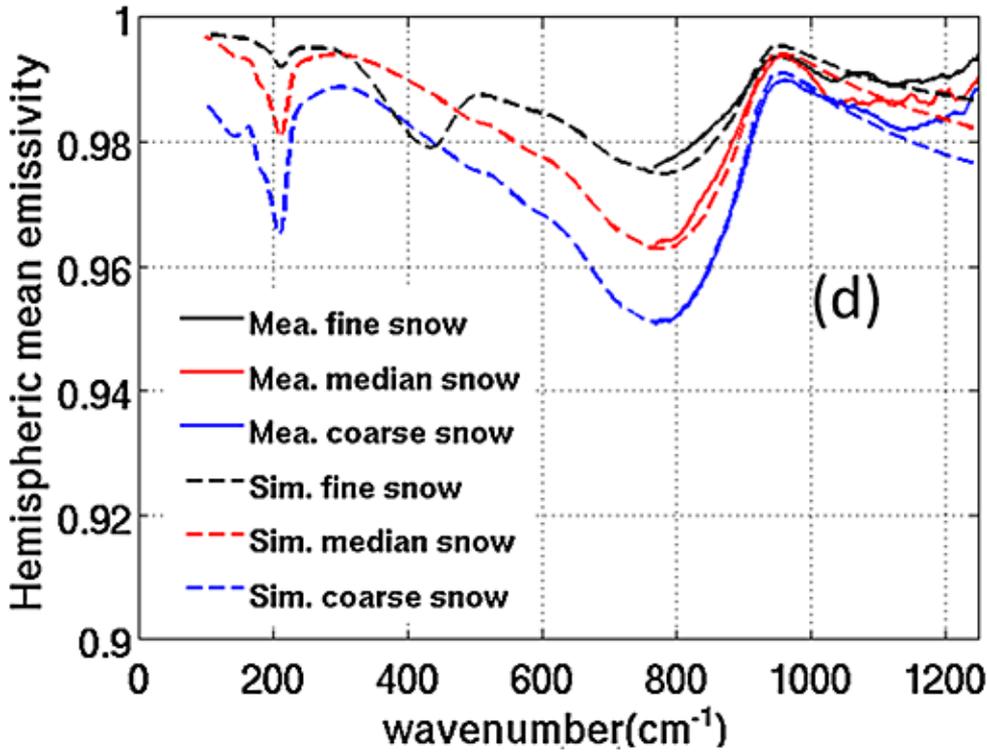
ASTER Database. **Such surface emissivity measurements usually stop at 14um (714cm<sup>-1</sup>)**  
**A simple extrapolation to the far-IR. The traditional wisdoms are (1) ... (2) ...**

**All GCMs still assume blackbody surface in their LW schemes (but not necessarily in land model)**

# Motivations (II)



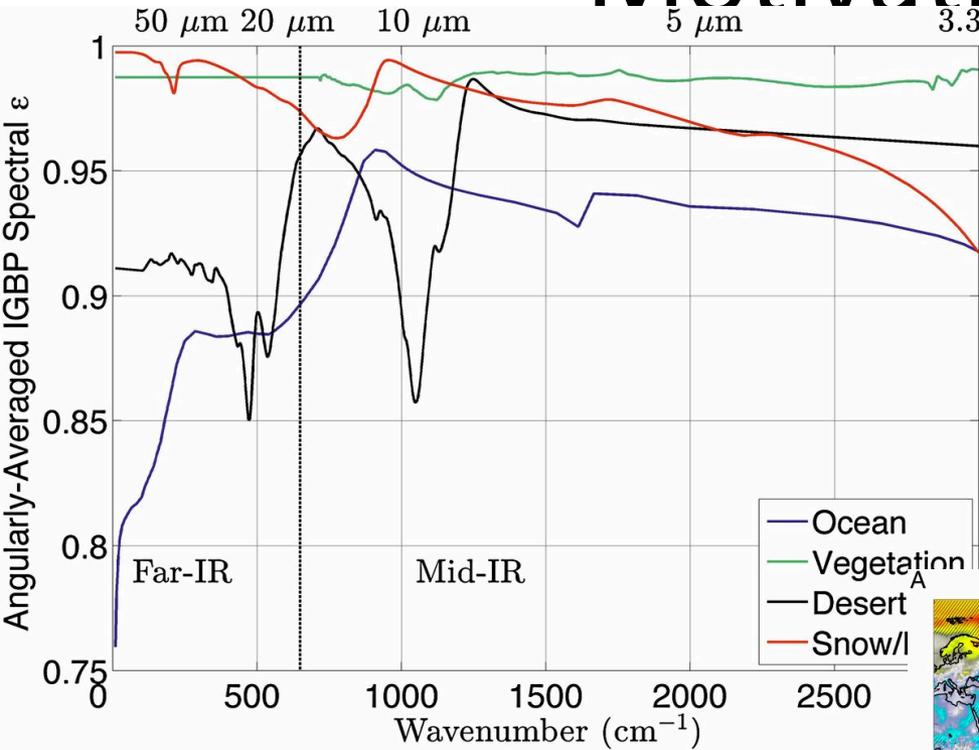
Annual-mean all-sky far-IR OLR change due to 1K change of  $T_s$ . (ERA-interim)



Simulated snow spectral emissivity vs. Measured snow spectral emissivity (Hori et al. 2006)

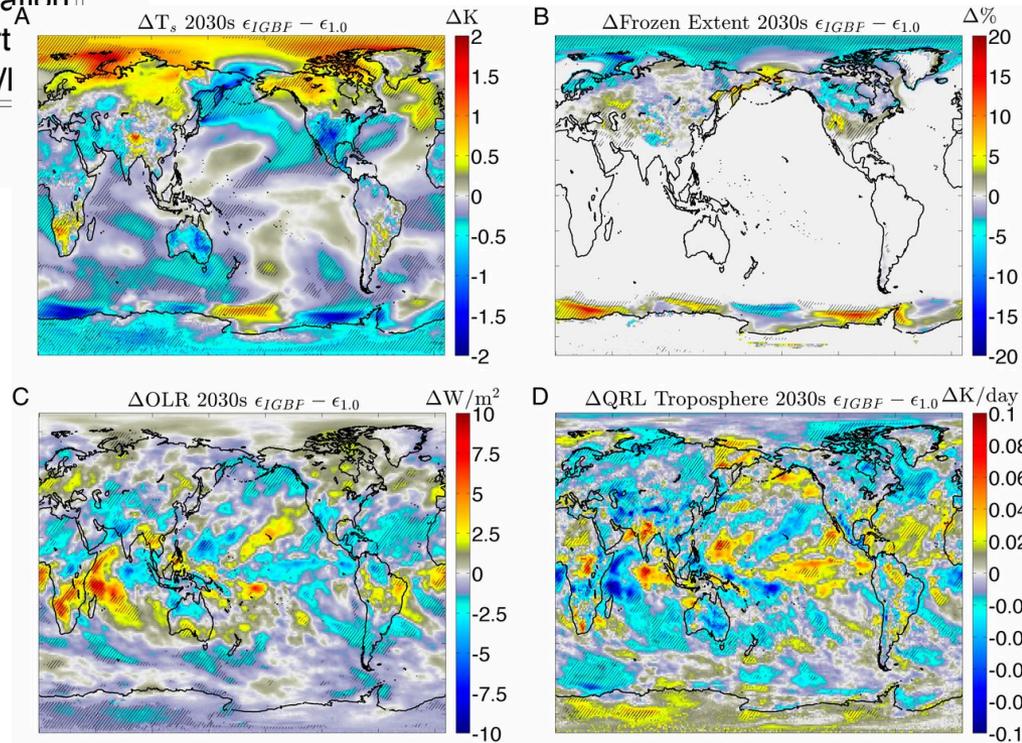
Chen, X. H., X. L. Huang, M. G. Flanner, [Sensitivity of modeled far-IR radiation budgets in polar continents to treatments of snow surface and ice cloud radiative properties](#), *Geophysical Research Letters*, doi:10.1002/2014GL061216, 2014.

# Motivations (III)



Vegetation is from ASTER database  
The rest are from the first-principle calculation

Feldman, D. R., W. D. Collins, R. Pincus, X. L. Huang, X. H. Chen,  
[Far-infrared surface emissivity and climate](https://doi.org/10.1073/pnas.1413640111),  
PNAS, doi: 10.1073/pnas.1413640111, 2014.



# Motivations (IV)

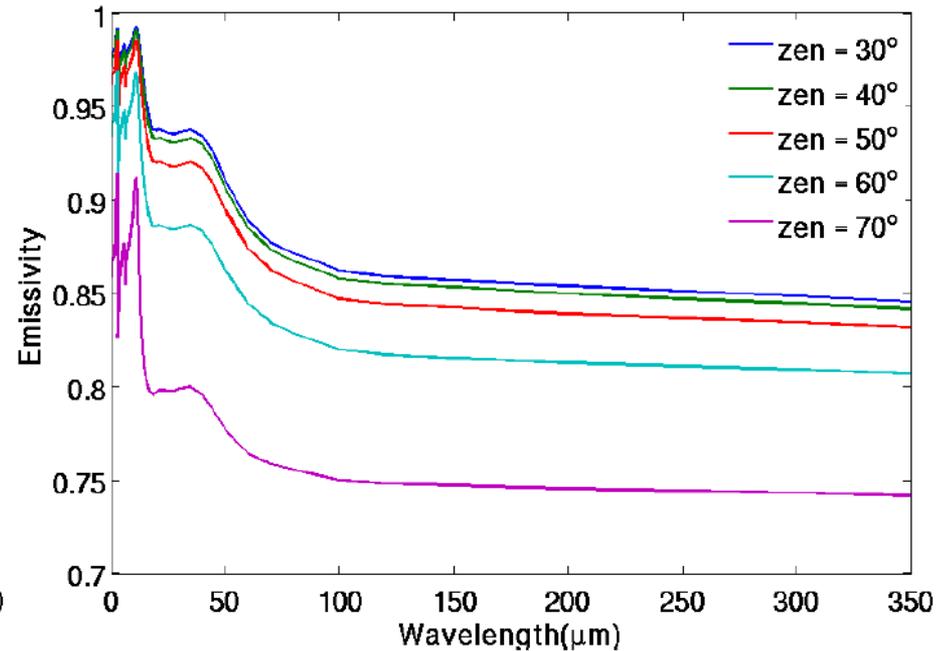
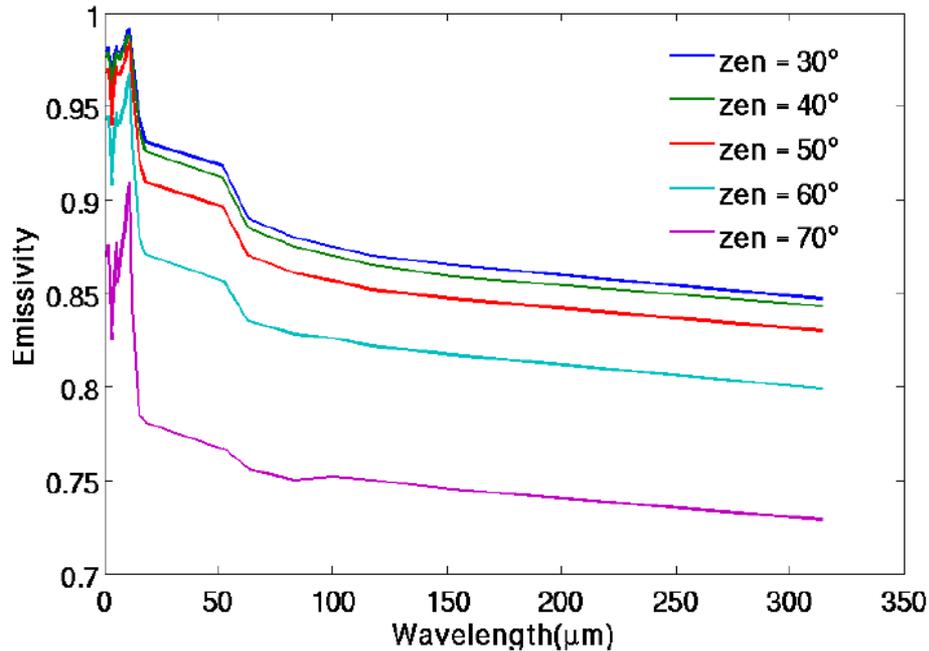
- The four-type surface spectral emissivity data set is really preliminary and for proof-of-concept
- Can we develop more sophisticated global surface emissivity data set with far-IR component included?
- What's the impact on OLR and surface energy balance?



# Constructing a global data set of surface emissivity suitable for GCMs

- Define 11 primary surface types
  - Desert, water, fine snow, medium snow, coarse snow, ice, grass, dry grass, conifer, deciduous, and a combination of conifer and deciduous
  - Calculating spectral surface emissivity for different surface types (vegetations from ASTER directly)
  - Calm ocean instead of rough ocean (errors within 0.02)

# Emissivity of pure water



**Table 4.43** in Mironova ZF (1973) Albedo of Earth's surface and clouds. In Kondrat'ev KYa ed. Radiation characteristics of the atmosphere and the Earth's surface. Amerind; New Delhi

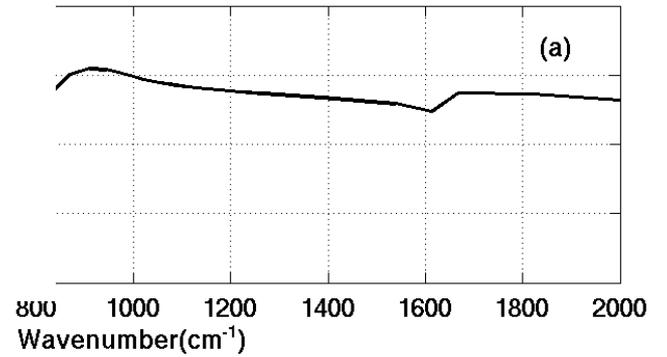
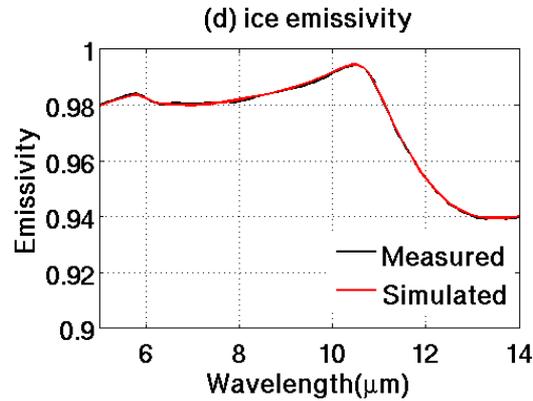
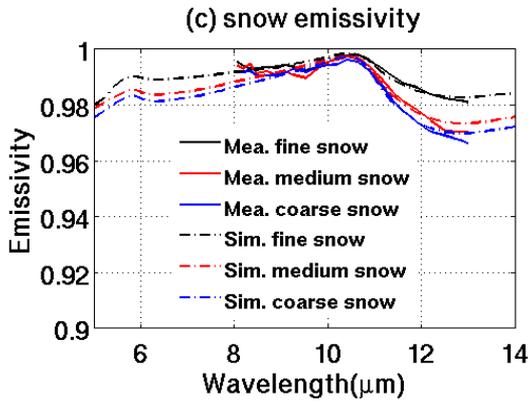
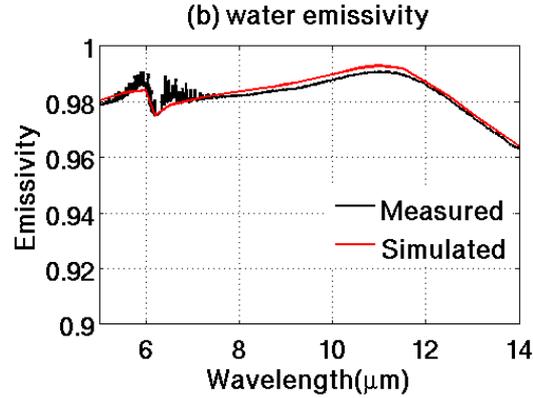
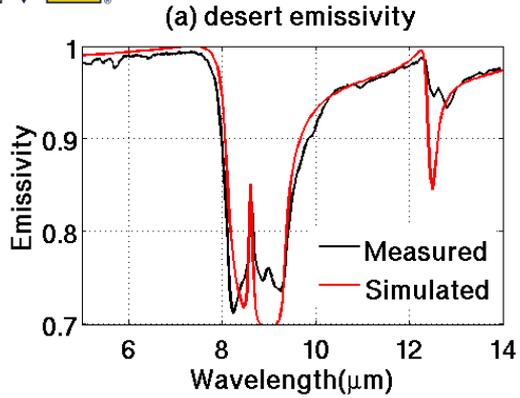
Computed using Fresnel equation and refractive index from Hale and Query, 1973

**Measured**

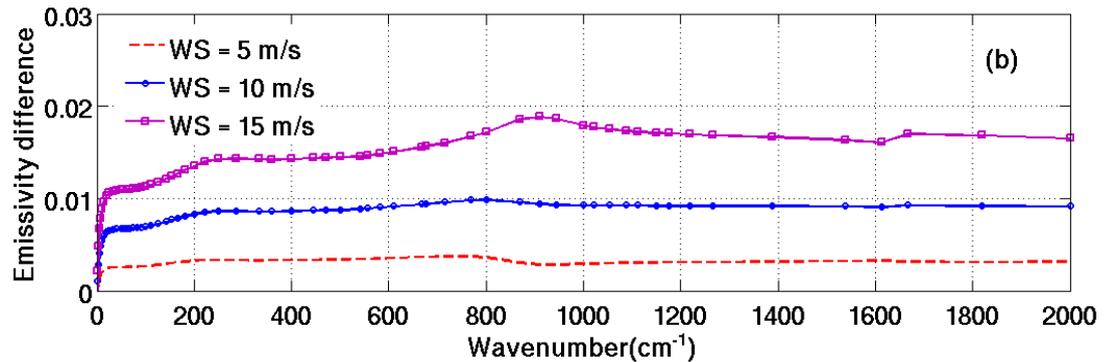
**Computed**



# Fresnel Equation



Scattering in densely packed medium



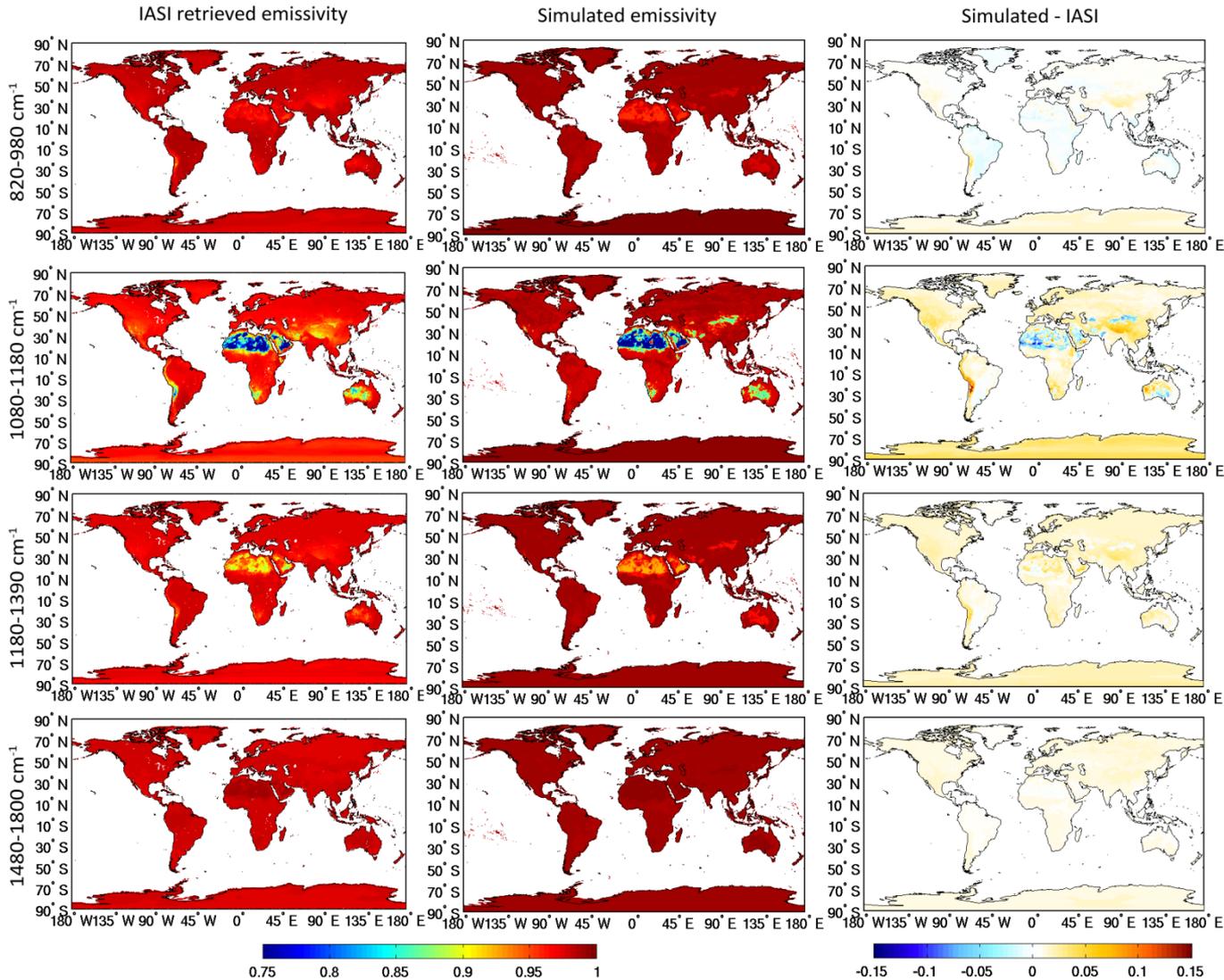


# Building global surface emissivity map

- Using Wisconsin CIMSS MODIS surface emissivity retrievals at 6 IR wavelengths and at  $0.05^{\circ} \times 0.05^{\circ}$  grid box
- For each gridbox, find the best match among the 11 surface types with MODIS retrieved surface emissivity at the 6 IR wavelengths
- Average onto  $0.5^{\circ} \times 0.5^{\circ}$  grid box and averaged onto RRTMG\_LW bandwidths
- Compare with IASI retrieved land surface emissivity over each RRTMG\_LW band on such  $0.5^{\circ} \times 0.5^{\circ}$  grid box



# Validations of global land spectral emissivity



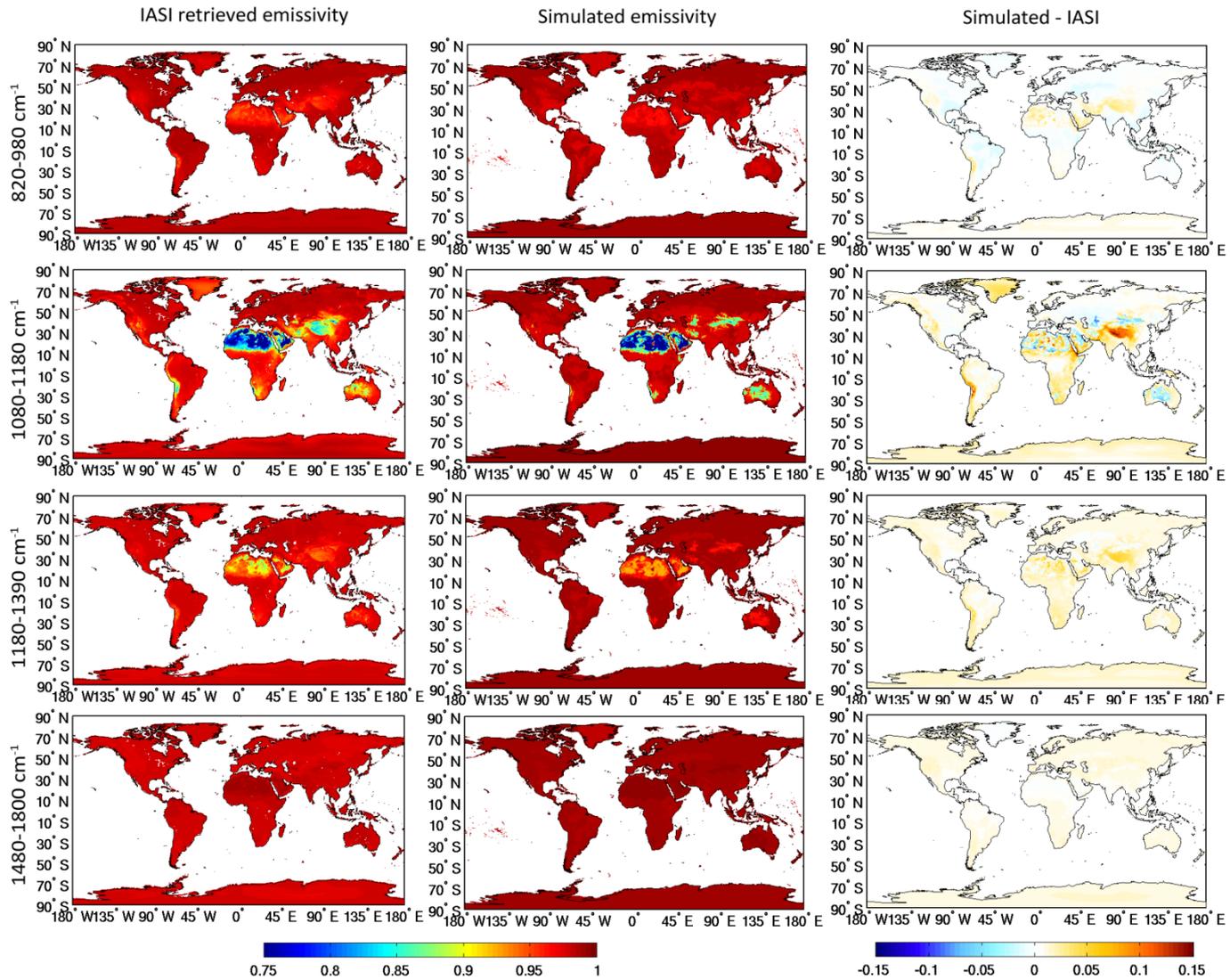
## Validation 1:

IASI emissivity ( $\epsilon_{IASI}$ )  
VS.  
Simulated emis. ( $\epsilon_{Sim.}$ )

January



# Validations of global land spectral emissivity



## Validation 1:

IASI emissivity ( $\epsilon_{IASI}$ )  
VS.  
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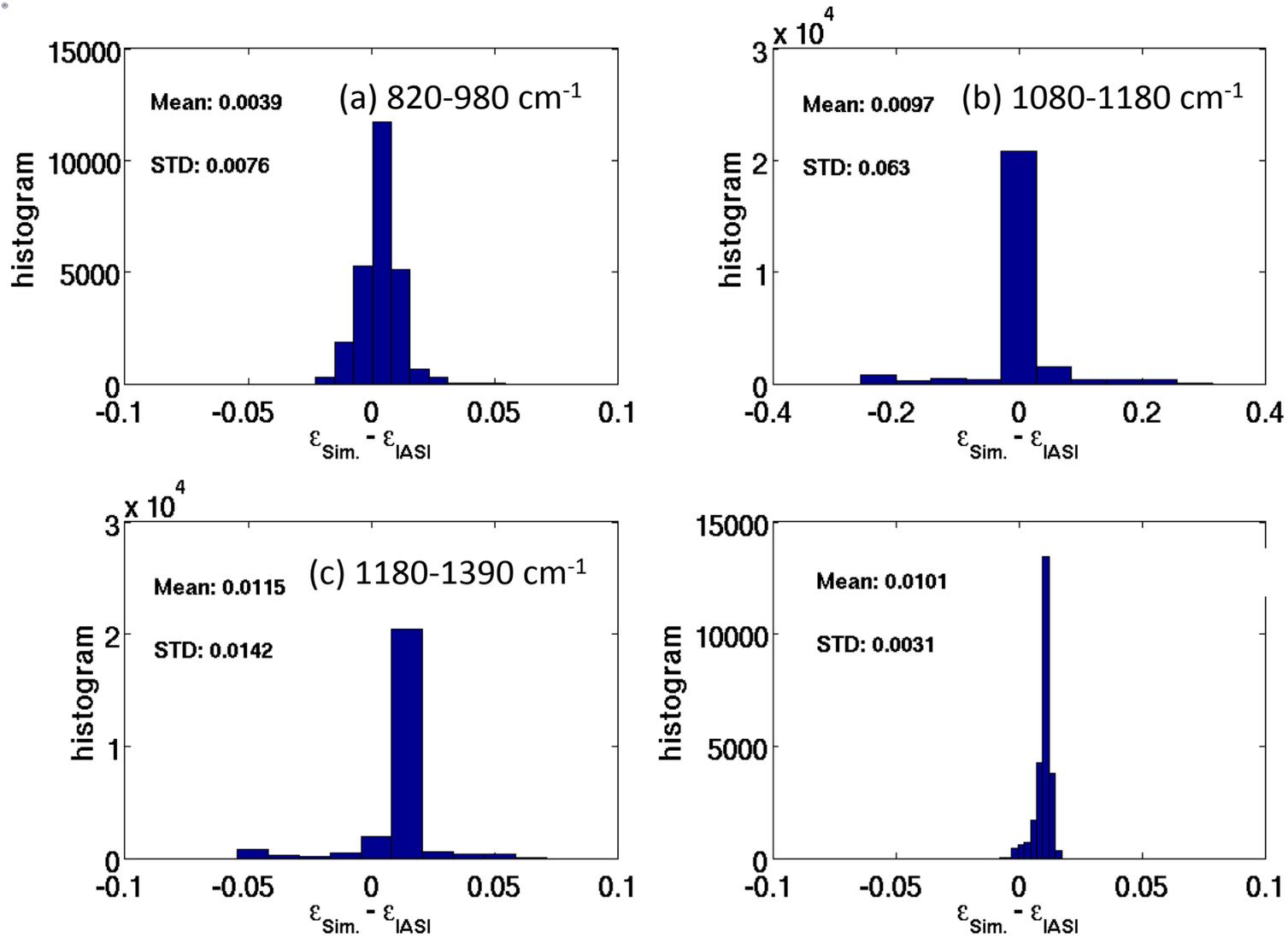
July

- four RRTMG bands:  
1<sup>st</sup> row: 820-980 cm<sup>-1</sup>;
- 2<sup>nd</sup> row: 1080-1180 cm<sup>-1</sup>;
- 3<sup>rd</sup> row: 1180-1390 cm<sup>-1</sup>
- 4<sup>th</sup> row: 1480-1800 cm<sup>-1</sup>.

on 0.5° by 0.5° grid-boxes.



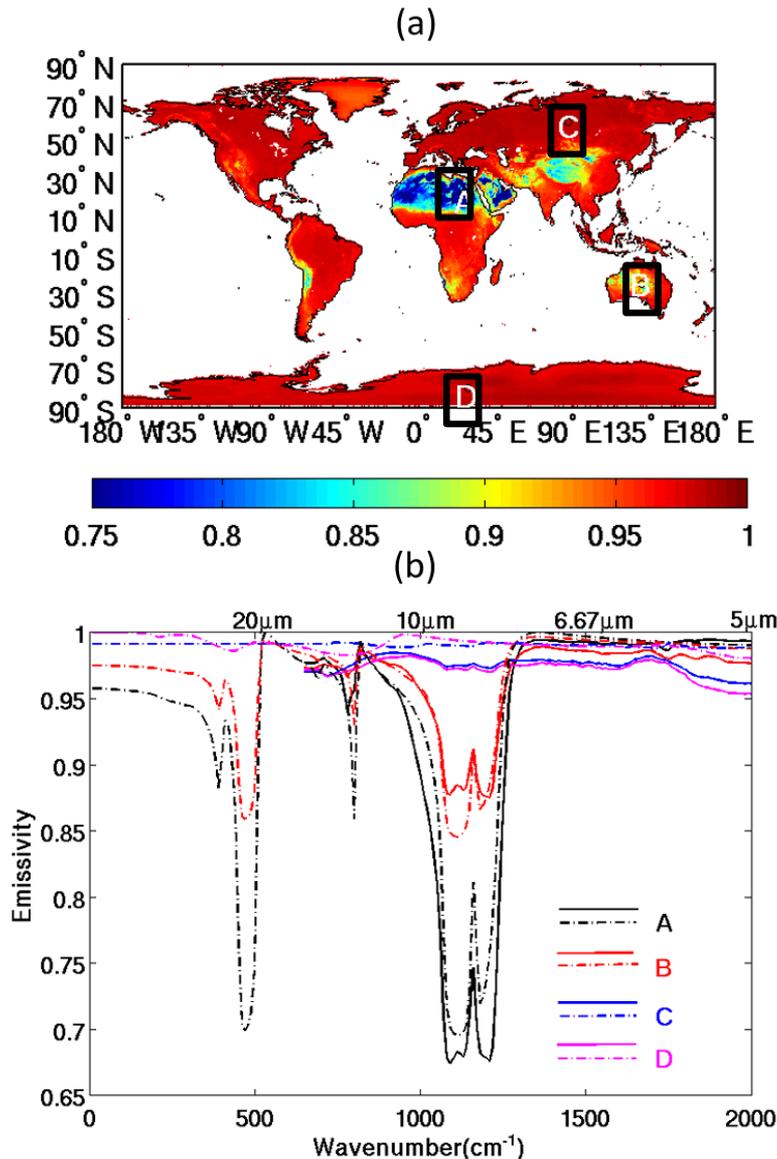
# Step 3 Validations of global land spectral emissivity



## Validation 2:

Histogram of  $\epsilon_{Sim.} - \epsilon_{IASI}$  for four bands. All data over lands and over  $0.5^\circ$  by  $0.5^\circ$  grids are used, 25439 in total. Mean difference and standard deviation are shown on each panel.

# Step 3 Validations of global land spectral emissivity



## Validation 3:

- (a) Illustration of four places.
- (b) IASI spectral emissivity VS. simulated spectral emissivity at spectral interval of 10 cm<sup>-1</sup>

Four places (A to D).

Place A (desert surface at 23°N, 27°E)

Place B (combined desert

and grass surface at 25°S, 135°E)

Place C (grass surface at 60°N, 90°E)

Place D (snow surface at 80°S, 30°E).

Solid lines : IASI emissivities

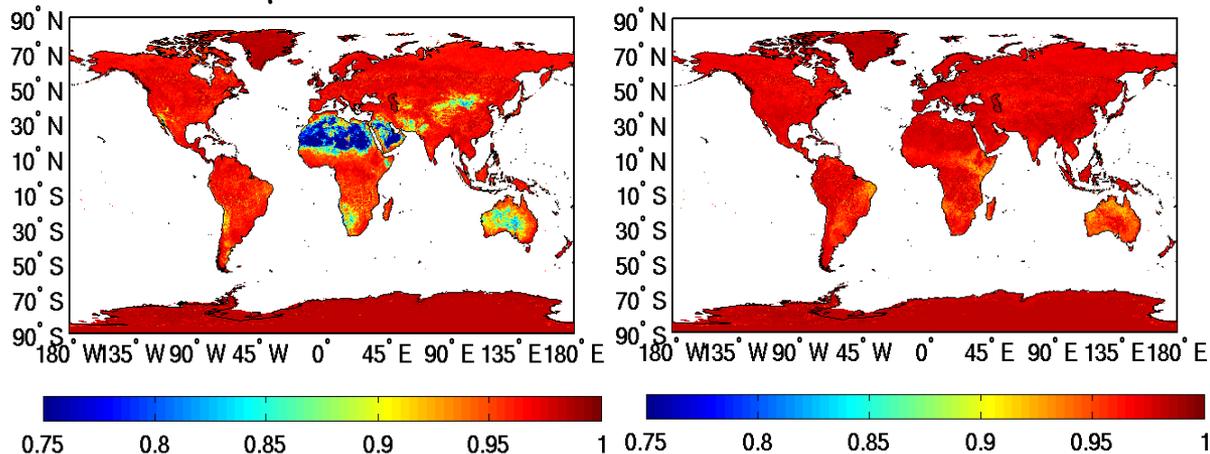
Dash-dot lines: simulated emissivities

# Emissivity from MODIS CIMSS

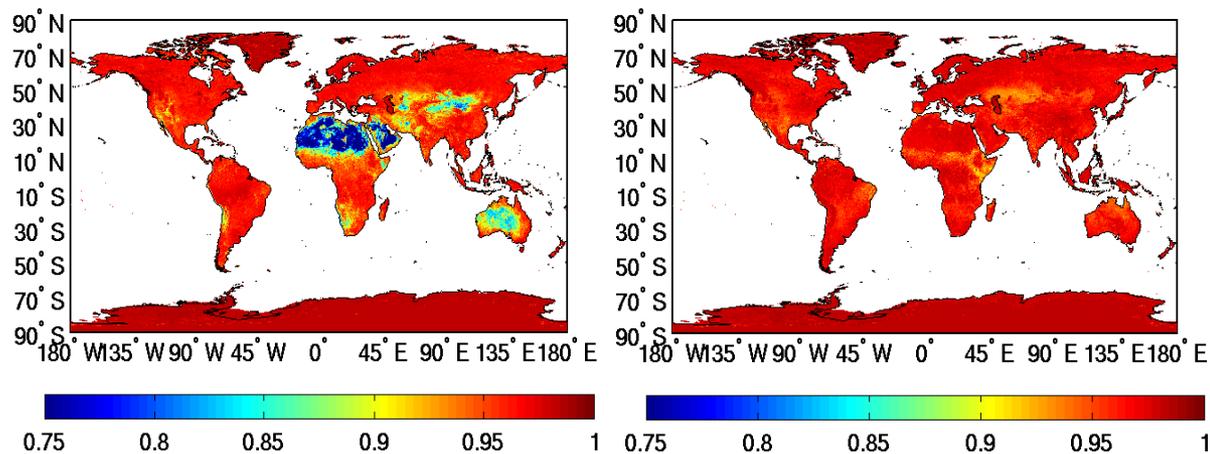
8.3  $\mu\text{m}$

12.1  $\mu\text{m}$

Jan2008



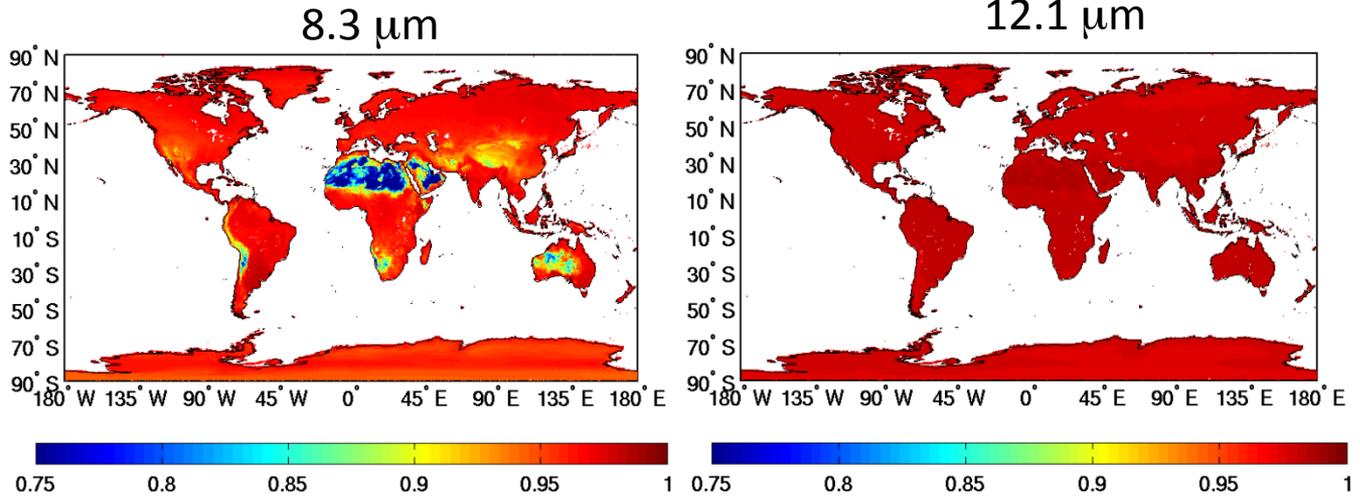
Jul2008



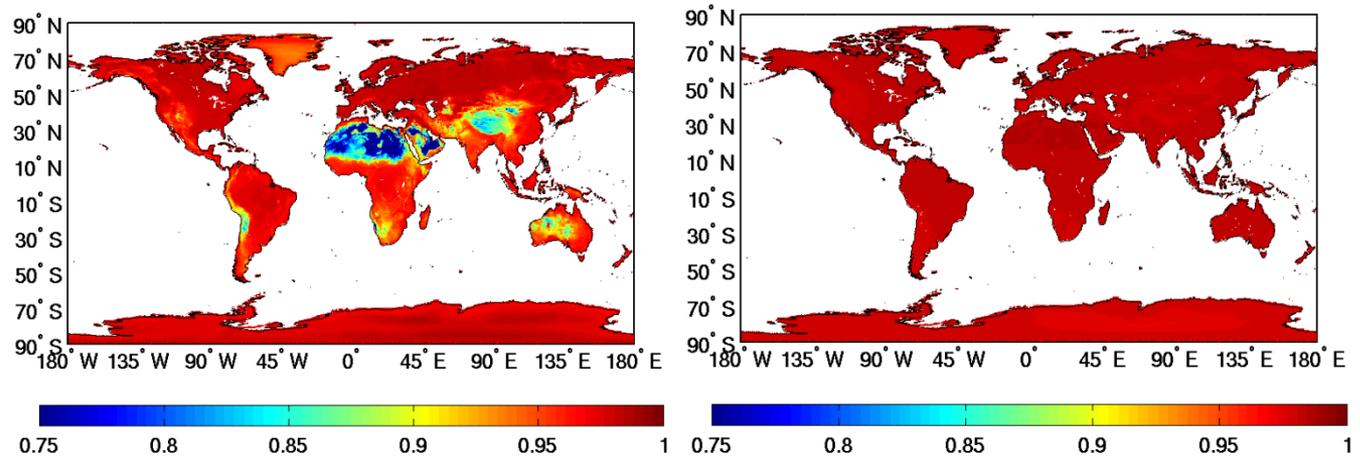
<http://cimss.ssec.wisc.edu/iremip/data/>

# Emissivity from IASI

Jan  
2008-2013



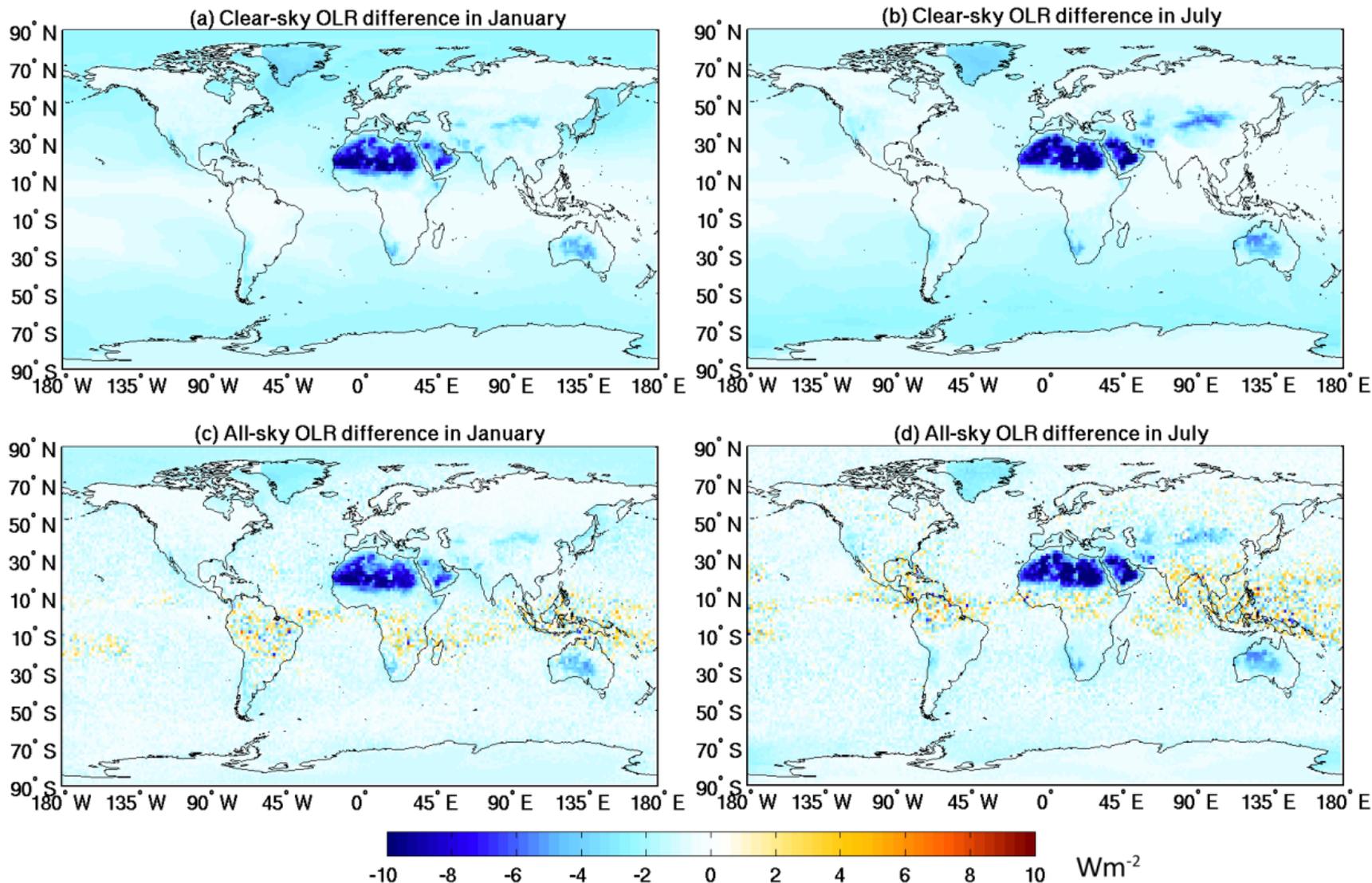
Jul  
2007-2014



IASI data is multi-year monthly mean

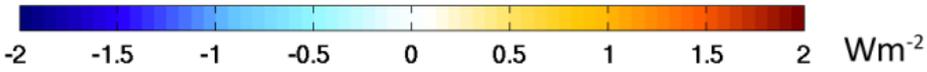
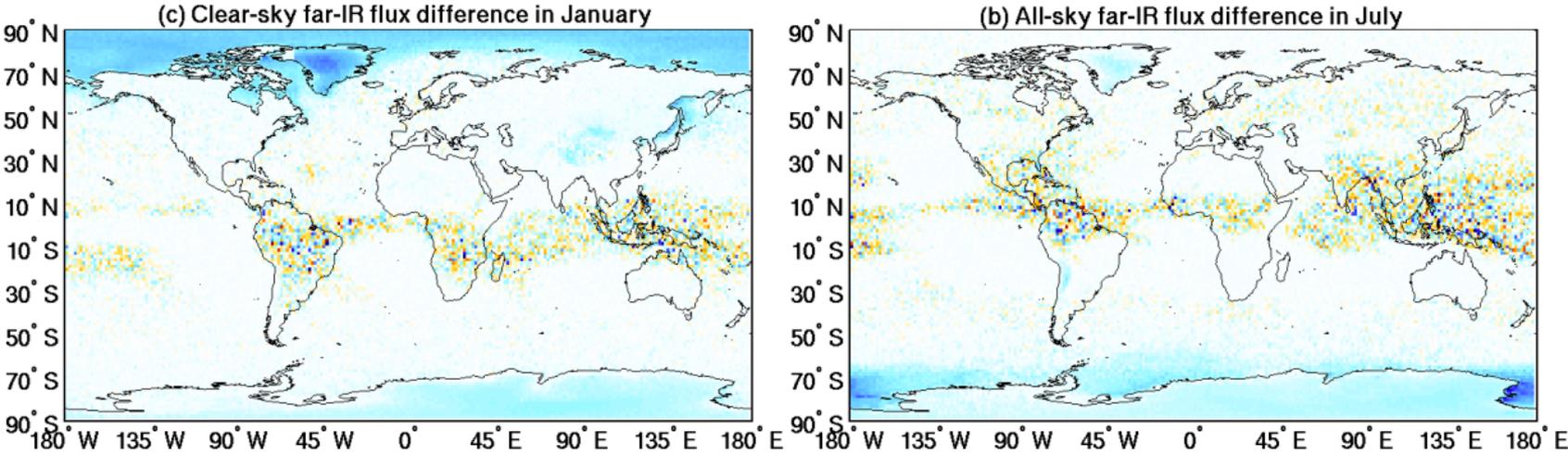
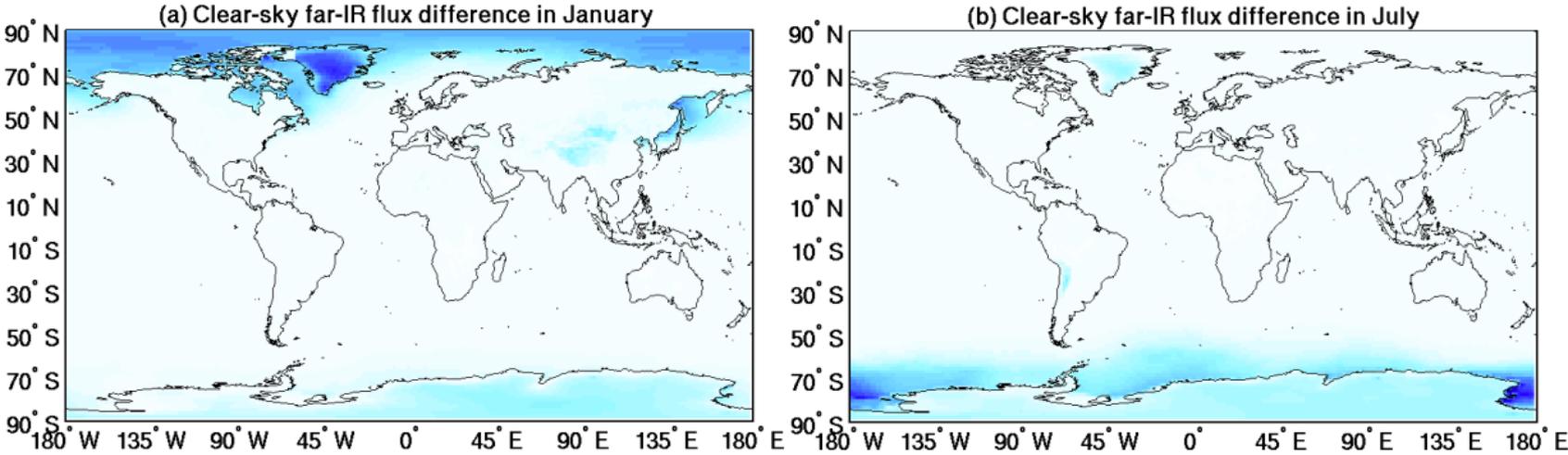
Impact on the OLR calculations

# OLR difference between non-blackbody and blackbody surface



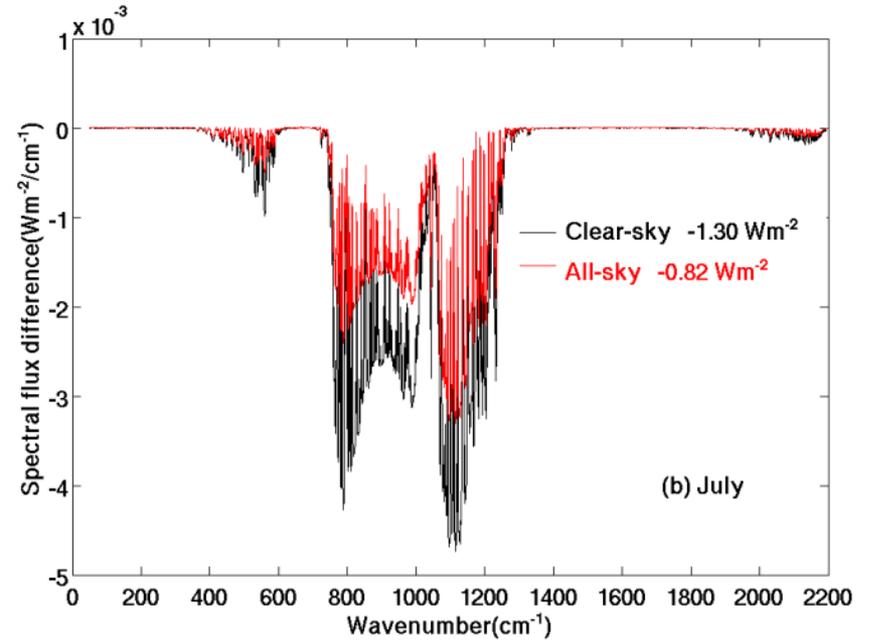
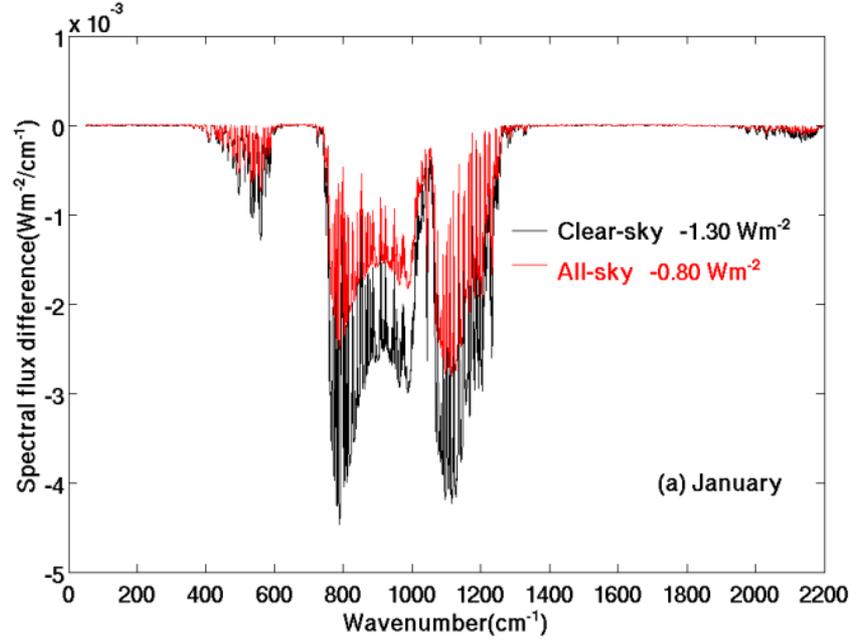
Atmosphere and cloud profiles are from 6-hourly ECMWF ERA in 2008  
PCRTM calculation

# Far-IR flux difference between non-blackbody and blackbody surface



Atmosphere and cloud profiles are from 6-hourly ECMWF ERA in 2008  
PCRTM calculation

# Monthly-mean spectral flux difference

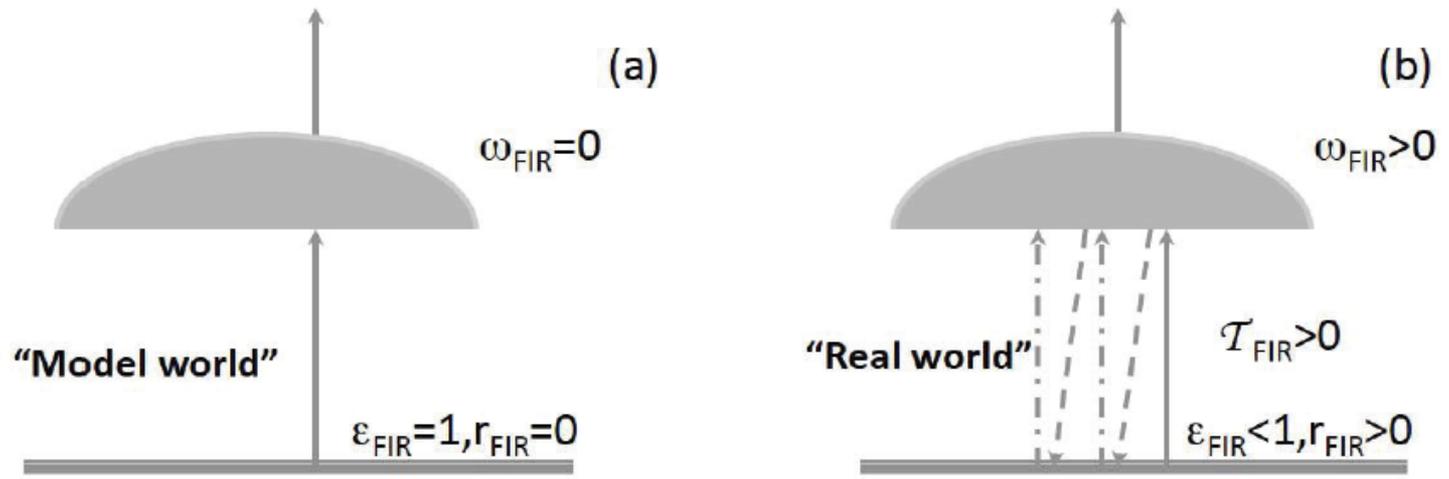


Computed on AWS EC2 instance: C3.8xlarge (32 vCPU, 60 G memory)

# Conclusions and discussions

- A global LW monthly surface spectral emissivity (including far-IR) dataset was developed.
- It is anchored on MODIS retrievals and validated against IASI retrievals
  - Mid-IR validation only
- There is  $\sim 0.01$  systematic bias w.r.t. IASI retrievals. Outstanding issues: Tibetan Plateau and deserts
- While all current GCMs still employ blackbody surface in LW scheme, surface emissivity should be taken into account.
- Still work in progress to refine the dataset. But it is available upon request (RRTMG\_LW, RRTM, Fu-Liou bandwidths)

# Model vs. Reality in the far-IR



(Chen et al., 2014)

*Question: how much this can alter the radiation budget at TOA and surface, and the net absorption of radiation by the atmosphere?*

Working hypothesis: (1) scattering reduces OLR and increase downward F @ sfc; (2) graybody emissivity decreases upward F @ sfc

**Clarification: net upward flux = (Upward flux – Downward flux)**  
**Net emission of atmos = OLR – net upward flux = (- Net absorption)**

# Fit MODIS CIMSS surface emissivity at 6 wavelengths 5.8, 7.6, 8.3, 9.3, 10.8, 12.1 $\mu\text{m}$

